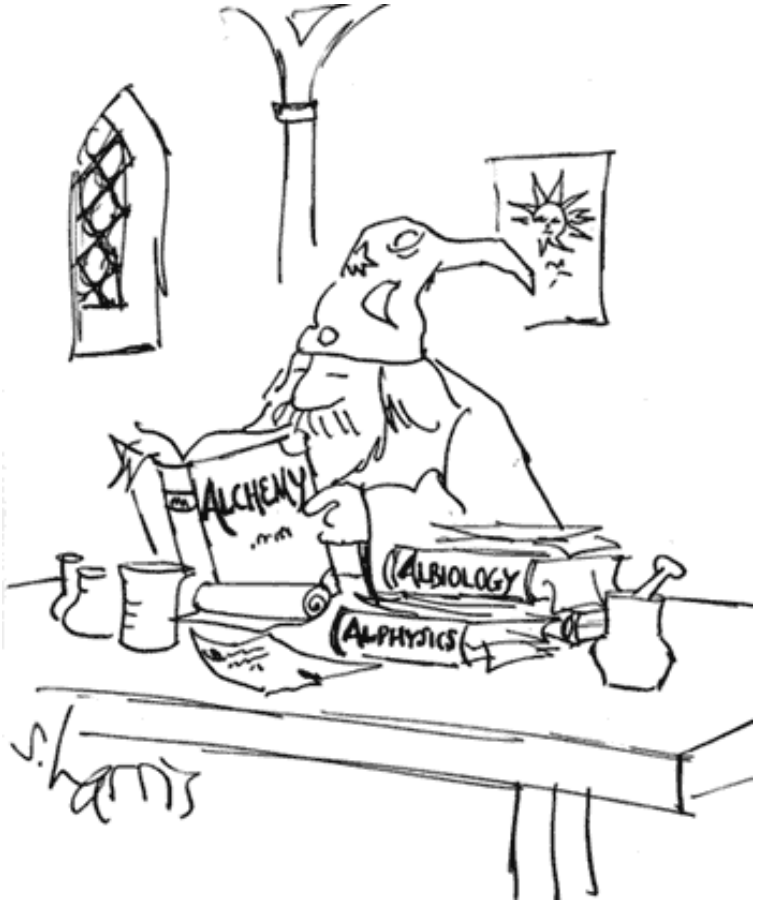
Chemical Equations
Writing and Balancing



Law of Conservation of Mass (or Matter)

- The principle behind writing and balancing equations is the **Law of Conservation of Mass (or Matter)**
  - In a chemical reaction, matter is neither created nor destroyed.
  - Bottom-line: You have to account for all of the atoms of an element that are involved in a chemical reaction.

Information from Chemical Equations

- First, they tell us what substances are reacting (those being used up) and what substances are products (those being made).
  - What substances you started with and what substances you end up with.
- Second, the coefficients of a balanced equation tell us in what ratio the substances react or are produced.

Coefficients are the numbers in front of the formulas.

- First: the coefficients give the number of molecules (or atoms) involved in the reaction.
- Second: the coefficients give the number of moles of each substance involved in the reaction
  - How much of what substances are involved and how much you should get.
  - A mole (mol) is the SI unit for the amount of matter.

Structure of a Chemical Equation

- The reactants are on the left side of a chemical equation and the products are on the right side.

Reactants $\longrightarrow$ Products

$$A + B \longrightarrow AB$$

Equation Nomenclature

- The sign, $\rightarrow$, means "yields" and shows the direction of the action.
- A double arrow, $\leftrightarrow$, shows that the reaction is reversible and can go in both directions.
- An up arrow $\uparrow$ means that the product is in the a gaseous state
- A down arrow $\downarrow$ means that a product is precipitating out of solution
- A small delta, (Δ), above the arrow shows that heat has been added.

Equation Nomenclature

- You will also see subscripted letters in chemical equations.

$$2AgNO_{3\,(aq)} + Cu_{(s)} \longrightarrow Cu(NO_3)_{2\,(aq)} + 2\,Ag_{(s)}$$

Symbol	Meaning	Defined
(*aq*)	Aqueous	In water
(*s*)	Solid	precipitate
(*l*)	Liquid	liquid state
(*g*)	Gas	gaseous state

The Magic 7 Diatomic Elements

- The diatomic elements when they stand alone**(FREE)** are always written H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2
- In addition to the above, phosphorous is P_4 and sulfur is S_8 are polyatomic molecules as free elements.
- Here is pneumonic that will allow you to easy remember the 7 diatomic elements.

Hydrogen **H_2**……	**H**ave
Nitrogen **N_2** …….	**N**o
Fluorine **F_2** ……	**F**ear
Oxygen **O_2** ……	**O**f
Iodine **I_2** ……	**I**ndigo
Chlorine **Cl_2** …….	**C**olored
Bromine **Br_2** …….	**B**unnies

Rules for writing equations

- Write down the formula(s) for any substance entering into the reaction. Place a plus (+) sign between the formulas as needed and put the yield arrow after the last one.

- Examine the formulas carefully and decide which of the four types of equations applies to the reaction you are considering. On the basis of your decision, write down the correct formulas for all products formed, placing them to the right of the arrow.

Balancing Rules

- Before beginning to balance an equation, check each formula to see that it is correct.
  - **NEVER** change a formula during the balancing of an equation if it is correct!!!!!
- Balancing is done by placing coefficients in front of the formulas to insure the same number of atoms of each element on both sides of the arrow.

$$\mathbf{2}\ A + \mathbf{3}\ B_2 \longrightarrow \mathbf{2}AB_3$$

Chemical Reaction Types

1) **Composition (combination or synthesis)**

General form: $A + X \longrightarrow AX$

2) **Double Replacement**

General form: $AX + BY \longrightarrow AY + BX$

3) **Single Replacement**

General form for **cation:** $M + BX \longrightarrow MX + B$

General form for **anion:** $BX + Y \longrightarrow BY + X$

End Part 1

Chemical Reaction Types

4) **Decomposition**:

a) Binary compounds

general form: $AB \xrightarrow{\Delta} A + B$

b) Metallic oxides

general form: $MO \xrightarrow{\Delta} M + O_2 \uparrow$

Chemical Reaction Types

c) Metallic hydroxides

general form: $MOH \xrightarrow{\Delta} MO + H_2O$

d)Metallic carbonates

general form: $MCO_3 \xrightarrow{\Delta} MO + CO_2$

f) Metallic bicarbonates (hydrogen carbonates)

general form: $MHCO_3 \xrightarrow{\Delta} MO + H_2O + CO_2$

g) Decomposition of selected acids

general form: $HnM \xrightarrow{\Delta} nMO + H_2O$

acid $\xrightarrow{\Delta}$ nonmetal oxide + water

Chemical Reaction Types

5) **Burning**

- hydrocarbons and related compounds (carbohydrates & alcohols)

General form: $C_xH_y + O_2 \longrightarrow CO_2 + H_2O$

General form : $C_xH_y + O_2 \xrightarrow{\text{limited}} CO + H_2O$

General form: $C_xH_y + O_2 \xrightarrow{\text{limited}} C + H_2O$

End Part 2

Synthesis (composition) Reactions

two or more elements or compounds may combine to form a more complex compound.

Basic form: $A + X \longrightarrow AX$

Examples:

$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$

$S_{8(s)} + 12\ O_{2(g)} \longrightarrow 8\ SO_3$

Synthesis (composition) Reactions

Examples:

barium & nitrogen

Aluminum & oxygen

Single Replacement Reactions

- a more active element takes the place of another element in a compound and sets the less active one free.

- Basic form:

$$A + BX \longrightarrow AX + B$$

$$AX + Y \longrightarrow AY + X$$

Single Replacement Reactions

- **NOTE:** Refer to the **activity series of metals and nonmetals** to predict products of replacement reactions.
- If the free element is above the element to be replaced in the compound, then the reaction will occur. If it is below, then no reaction occurs.

The activity series of metals and nonmetals

- to predict products of replacement reactions. If the free element is above the element to be replaced in the compound, then the reaction will occur.
- If it is below, then no reaction occurs.

- You will need to reference you activity series sheet.

Single Replacement Reactions

- Each element on the list replaces from a compound any of the elements below it. The larger the interval between elements, the more vigorous the reaction.
- The first five elements (lithium - sodium) are known as very active metals and they react with cold water to produce the hydroxide and hydrogen gas.
- The next four metals (magnesium - chromium) are considered active metals and they will react with very hot water or steam to form the oxide and hydrogen gas.
- The oxides of all of these first metals resist reduction by H_2.

Single Replacement Reactions

- The next six metals (iron - lead) replace hydrogen from HCl and dil. sulfuric and nitric acids. Their oxides undergo reduction by heating with H_2, carbon, and carbon monoxide.
- The metals lithium - copper, can combine directly with oxygen to form the oxide.
- The last five metals (mercury - gold) are often found free in nature, their oxides decompose with mild heating, and they form oxides only indirectly.

Single Replacement Reactions

- Examples of single replacement reactions
- Replacement of a metal by a more active metal.
  EX. $Fe_{(s)} + CuSO_{4(aq)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$
- Replacement of hydrogen in acids by active metals. EX. $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$
- Replacement of nonmetals by more active nonmetals. EX.
  $Cl_{2(g)} + 2NaBr_{(aq)} \rightarrow 2NaCl_{(aq)} + Br_{2(l)}$

Single Replacement Reactions

- Examples:
- $Fe_{(s)} + CuSO_{4(aq)} \rightarrow$

- $Au_{(s)} + FeSO_{4(aq)} \rightarrow$

Double Replacement Reactions (Ionic Reactions)

occurs between ions in aqueous solution.

A reaction will occur when a pair of ions come together to produce at least one of the following:

- a precipitate
- a gas
- water or some other non-ionized substance.

Basic form: $AX + BY \rightarrow AY + BX$

Double Replacement Reactions (Ionic Reactions)

- Formation of precipitate.

$$NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$$

- Formation of a gas.

$$HCl_{(aq)} + FeS_{(s)} \rightarrow FeCl_{2(aq)} + H_2S_{(g)}$$

- Formation of a product which decomposes.

$$CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

- Formation of water. (neutralization reaction.)

EX. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Double Replacement Reactions (Ionic Reactions)

- Use the **solubility rules** to decide whether a **product** of an ionic reaction is insoluble in water and will thus form a **precipitate**.
- If a compound is soluble in water then it should be shown as being in aqueous solution, or left as separate ions.

Complete & Net Ionic Reactions

- The double replacement version:

$$AgNO_3 + KCl \longrightarrow KNO_3 + AgCl$$

- The complete ionic equation:

$$Ag^+_{(aq)} + NO_3^{-1}{}_{(aq)} + K^+_{(aq)} + Cl^{-1}_{(aq)} \longrightarrow K^+_{(aq)} + NO_3^{-1}{}_{(aq)} + AgCl_{(s)}$$

- The net ionic equation will look like this:

$$Ag^+_{(aq)} + Cl^{-1}_{(aq)} \longrightarrow AgCl_{(s)}$$

Spectator Ions

- A spectator ion is an ion which does not participate in a reaction.

  They are not part of the precipitate
- These ions will hang out in the water solution and watch the precipitate come out of solution.

Solubility Rules

- All common compounds of Group I and ammonium ions are soluble.
- All nitrates, acetates, and chlorates are soluble.
- All binary compounds of the halogens (other than F) with metals are soluble, except those of Ag, Hg(I), and Pb. Pb halides are soluble in hot water.)
- All sulfates are soluble, except those of barium, strontium, calcium, lead, silver, and mercury (I). The latter three are slightly soluble.

Solubility Rules

- Except for rule 1, carbonates, hydroxides, oxides, silicates, and phosphates are insoluble.
- Sulfides are insoluble except for calcium, barium, strontium, magnesium, sodium, potassium, and ammonium.
- See chart for easy determination.

Complete & Net Ionic Reactions

- Examples:

$$2\,KI + Pb(NO_3)_2 \longrightarrow 2\,KNO_3 + PbI_{2(\downarrow)}$$

Complete & Net Ionic Reactions

- Examples:

Decomposition

- A single compound breaks down into its component parts or simpler compounds.

- **Basic form: AX → A + X**

Examples of decomposition reactions:

- If the compound has two elements (binary) break the compound into the two elements

$$2\,H_2O \xrightarrow{electrcity} 2H_2 + O_2$$

How to figure out the right products:

- (1) Identify the type of compound decomposing:
  - Notice that you have to be able to identify the parts that make it up.
- (2) Apply the rule for that type:
- (3) Write two new (CORRECT!!) formulas using the rule from step two.

Examples of decomposition reactions:

More than two elements: metal plus a polyatomic ion

Metal chlorates $\longrightarrow$ metal chloride + O_2

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$$

Metal hydroxide $\longrightarrow$ metal oxide + H_2O

$$2NaOH \xrightarrow{\Delta} Na_2O + H_2O$$

Metal bicarbonates $\longrightarrow$ metal oxide + CO_2 + H_2O

(hydrogen carbonates)

$$2CsHCO_3 \xrightarrow{\Delta} Cs_2O + 2CO_2 + H_2O$$

Examples of decomposition reactions:

More than two elements: metal plus a polyatomic ion

Metal carbonates $\longrightarrow$ metal oxide + CO_2

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$

Examples of decomposition reactions:

- Heating potassium bicarbonate:

- Heating silver oxide:

Examples of decomposition reactions:

- Heating strontium hydroxide

- Heating zinc carbonate

Combustion of Hydrocarbons

- Another important type of reaction is that of the combustion of hydrocarbons such as propane, butane and gasoline.

- When a hydrocarbon is burned with sufficient oxygen supply, the products are always carbon dioxide and water vapor.

Combustion of Hydrocarbons

- If the supply of oxygen is low or restricted, then carbon monoxide will be produced.
  - This is why it is so dangerous to have an automobile engine running inside a closed garage or to use a charcoal grill indoors.
  - This can also occur with wood stoves and heating systems that rely on fossil fuels when the systems are not properly maintained.

Combustion of Hydrocarbons

- If the supply of oxygen is very low or restricted, then soot (particulate carbon) will be produced.
  - This makes a big mess when the carbon particles float through the air and stick to surfaces.

Combustion of Hydrocarbons

- **Complete combustion** means the higher oxidation number is attained.
- **Incomplete combustion** means the lower oxidation number is attained.
- **The phrase "To burn"** means to add oxygen unless told otherwise.
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Combustion of Hydrocarbons

$$(C_xH_y) + O_{2(g)} \longrightarrow CO_{2(g)} + H_2O_{(g)}$$

There are 2 types of burning reactions we will consider:

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

$$2C_4H_{10(g)} + 9O_{2(g)} \xrightarrow{\text{limited}} 8CO + 10\ H_2O_{(g)}$$

Combustion of Hydrocarbons

Examples:

$$C_5H_{12} + O_2 \longrightarrow$$

$$C_3H_8 + O_2 \xrightarrow{\text{limited}}$$

OR

$$C_3H_8 + O_2 \xrightarrow{\text{limited}}$$

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That's All Folks!!!!!